Evaluation of the effect of an explosive charge close to a steel structure plate

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Outline of the presentation

1 – Introduction

2 – Experimental set up and results (picture of the target)

3 – Energy balance – deformation and petalisation

4 – Momentum balance – shear wave displacement

5 – Picture of the phenomenon during the time

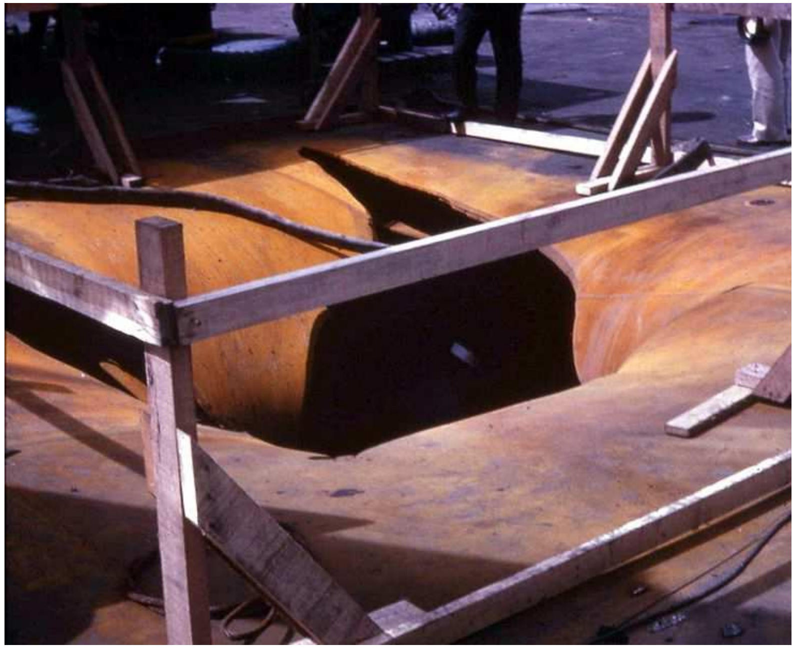
6 – Local ejected part velocity

7 – Both close charges

8 – Conclusion

EXPLOSIVE CLOSE TO A METALLIC PLATE : Introduction

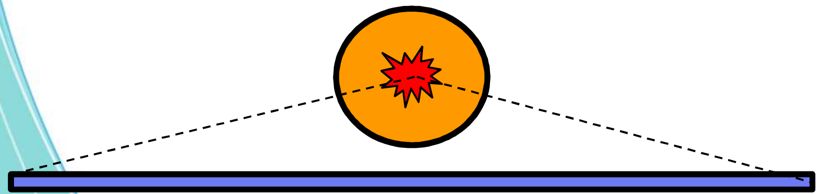
Explosive charge close to a plate



A strong localised loading for the structure of a ship

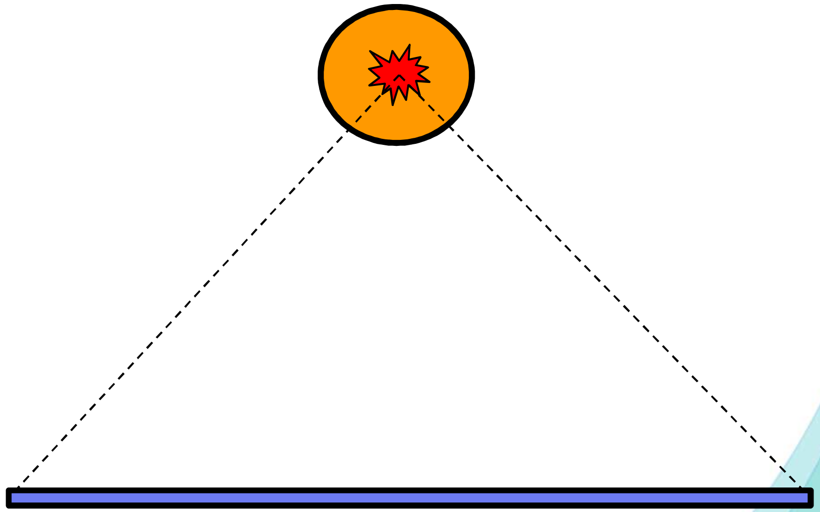
EXPLOSIVE CLOSE TO A METALLIC PLATE : Introduction

Short stand-off



strong localized deformation of the plate

Long stand-off



Smooth global deformation of the plate

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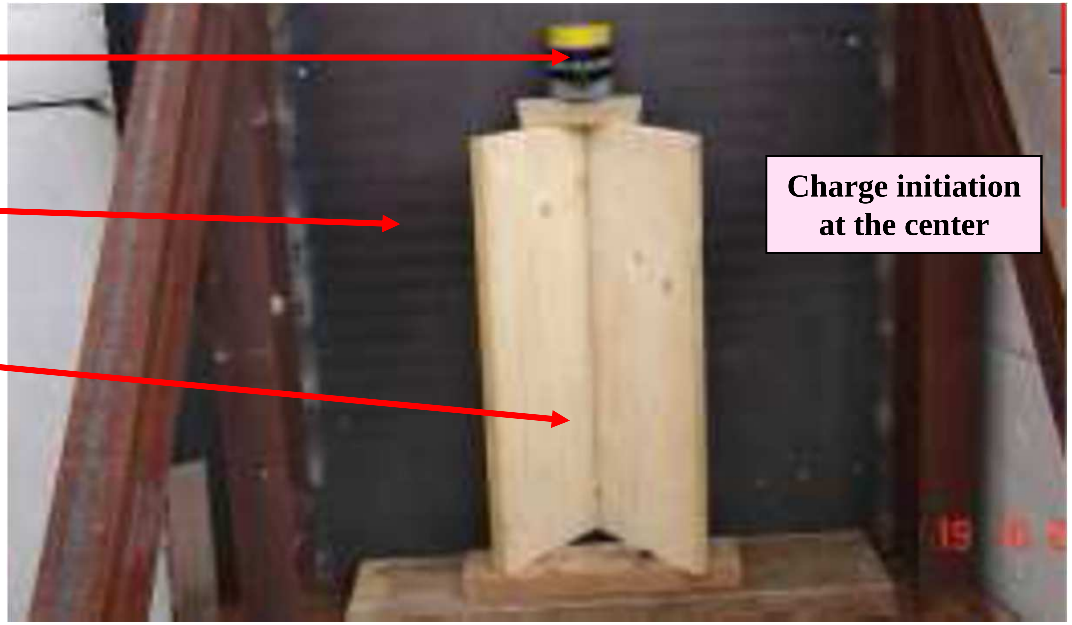
EXPLOSIVE CLOSE TO A METALLIC PLATE : Experimental set up

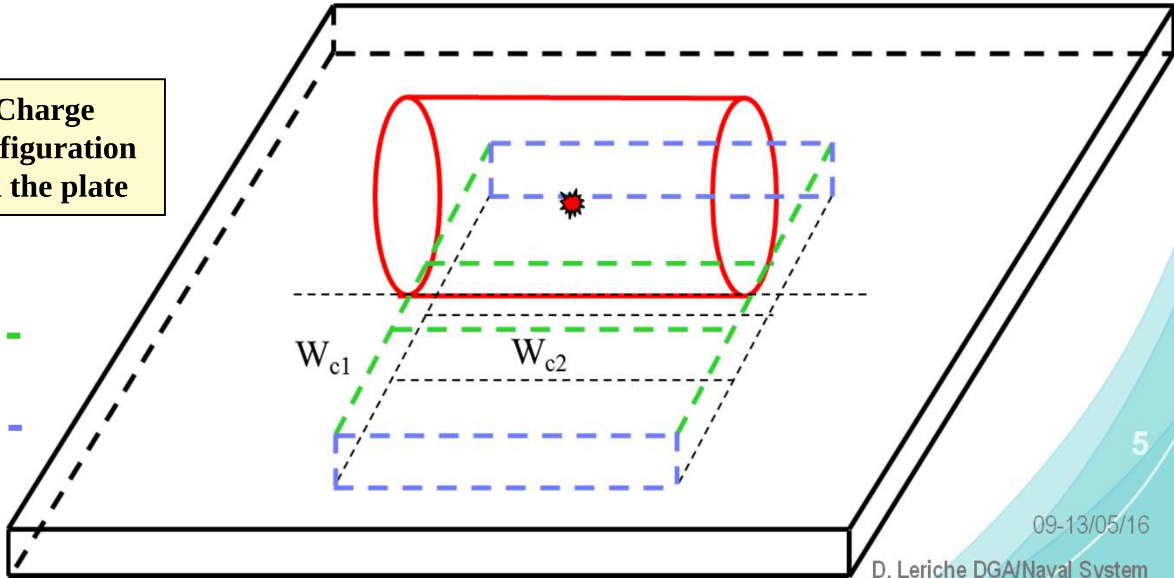
Explosive charge

Vertical steel plate

Wood support



Charge configuration on the plate



Shear line - - - - -

Plastic hinge - - - - -

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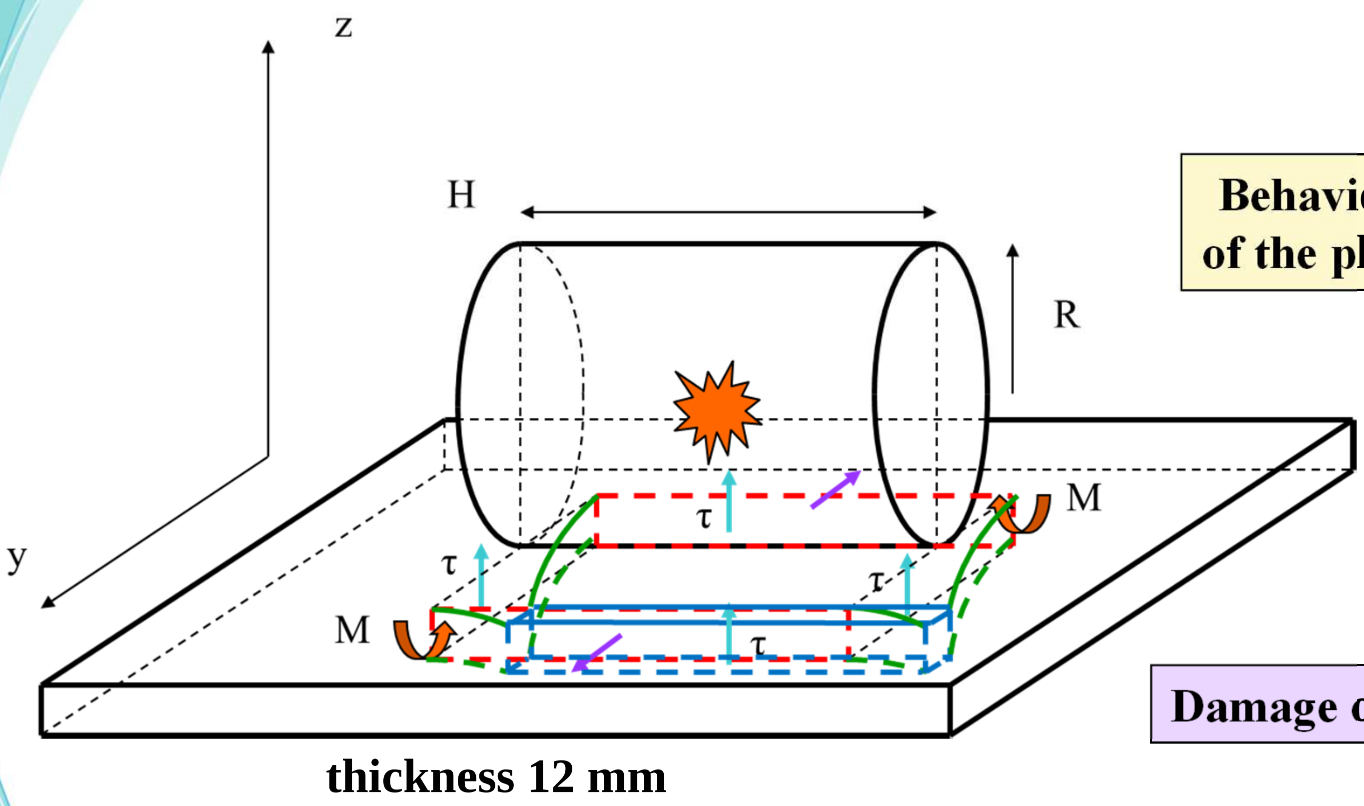
EXPLOSIVE CLOSE TO A METALLIC PLATE : Experimental results



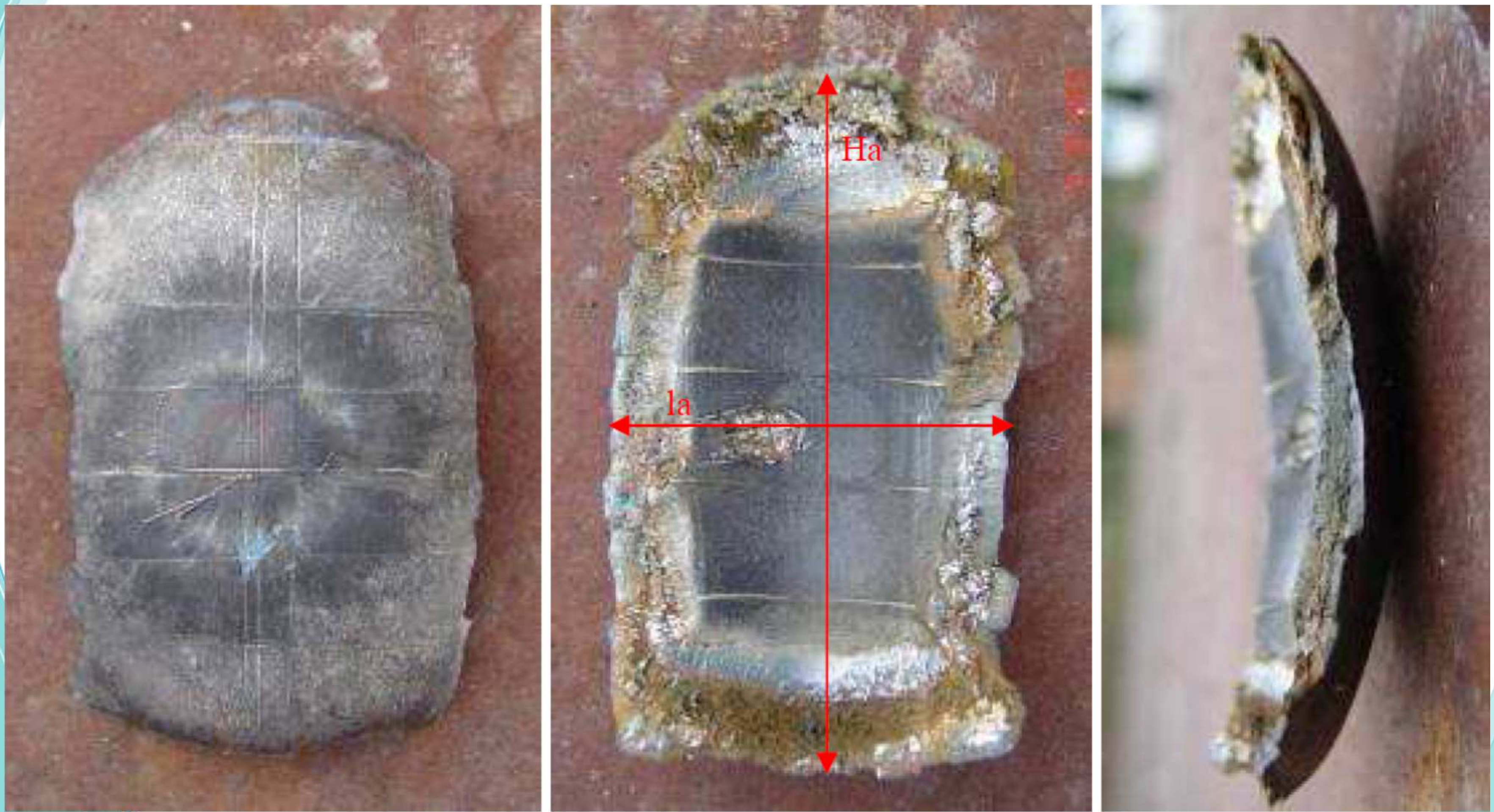
Behavior of the plate

Damage on the plate

EXPLOSIVE CLOSE TO A METALLIC PLATE : Experimental results

Damage on the plate and ejected part

EXPLOSIVE CLOSE TO A METALLIC PLATE : Experimental results



Dimension of the ejected part

EXPLOSIVE CLOSE TO A METALLIC PLATE : Deformation and petalisation

Energy E_m of the mechanical effects on the plate are:

*longitudinal shear energy W_{c1}
*transversal shear energy W_{c2}
*bending energy of both shaped petals W_b
*kinetic energy of the main ejected part E_{cd}

W_b

W_{c1}

W_{c2}

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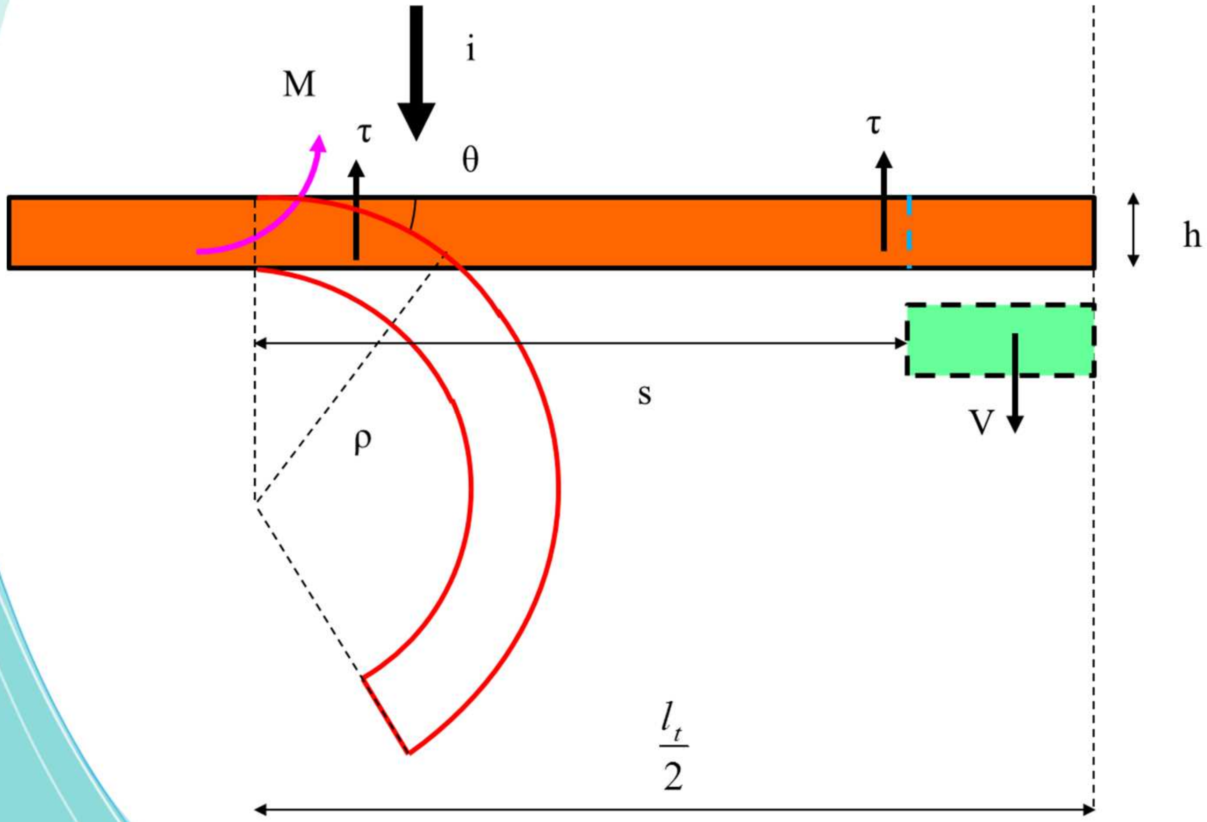
EXPLOSIVE CLOSE TO A METALLIC PLATE : Deformation and petalisation



Shear energy given by :

$$W_{c1} = \frac{\tau . l_t . h^2}{2}$$

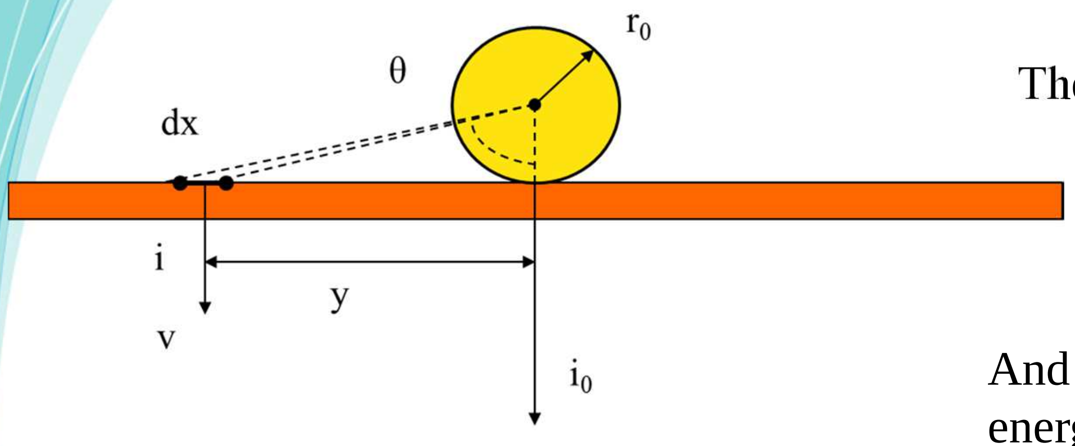
$$W_{c2} = \frac{\tau . H_a . h^2}{2}$$

Bending energy given by :

$$W_b = \frac{\sigma_e . s . b . h^2}{4 . \rho}$$

Schema of the effects on the plate

EXPLOSIVE CLOSE TO A METALLIC PLATE : Deformation and petalisation



The local specific impulse is given by

$$i = i_0 . \cos^4 \theta$$

And we suppose that the specific kinetic energy is given by:

$$e = \frac{i^2}{2.\rho.h}$$

The whole transmitted energy to the plate by the explosive is given by:

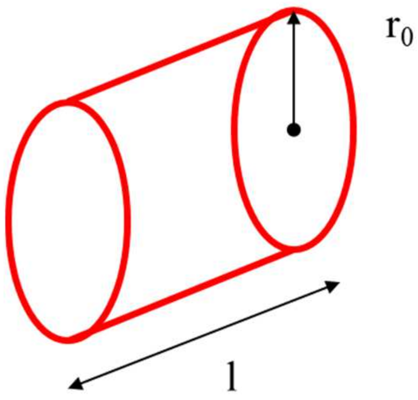
$$E_m = 2.\int_0^y \frac{i^2}{2.\rho.h}.dy = 2.W_b + 2.W_{c1} + 2.W_{c2} + E_{cd}$$

E_{cd} is the kinetic energy of the ejected part.

EXPLOSIVE CLOSE TO A METALLIC PLATE : Deformation and petalisation

From the equality of the energy, we have :

Test	1	2
i_0 (N.s/m²)	72516,7	65424



Explosif	Plastrite
W (kg)	1
l (m)	0,117
r_0 (m)	0,045

From the experimental results, we have also :

$$i_0 = \rho . h . V_1$$

V_1 is the local ejected part velocity
ρ is the thickness of the plate
h is the thickness of the plate

$$i_0 = 66000 \quad N.s / m^2$$

$$I = i_0 . S = 2602 \quad N.s$$

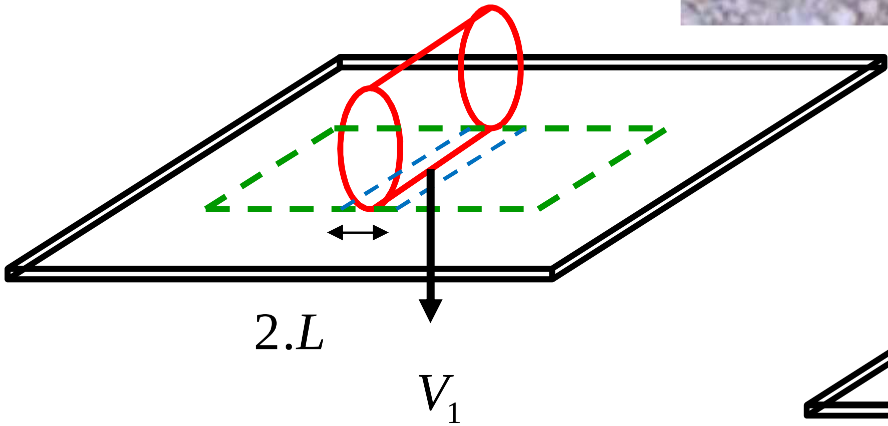
I total impulse of the explosive
S surface of the explosive charge

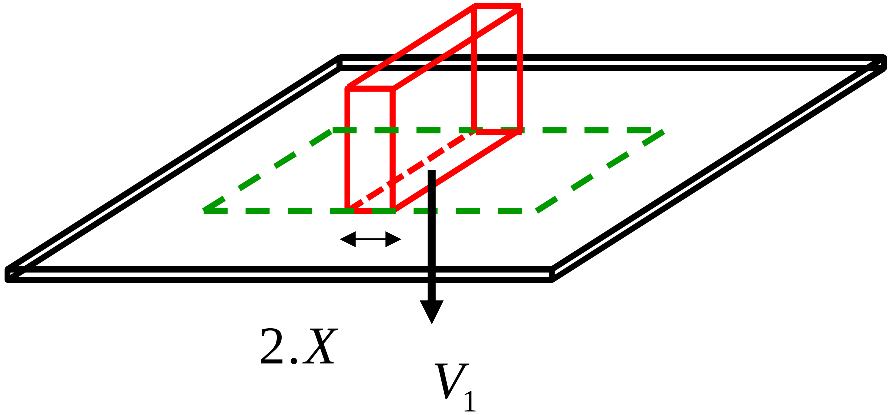
$$\boxed{I = \frac{8}{27} . W . D}$$

Orlenko's relation

EXPLOSIVE CLOSE TO A METALLIC PLATE : Momentum balance

Equivalent impulse



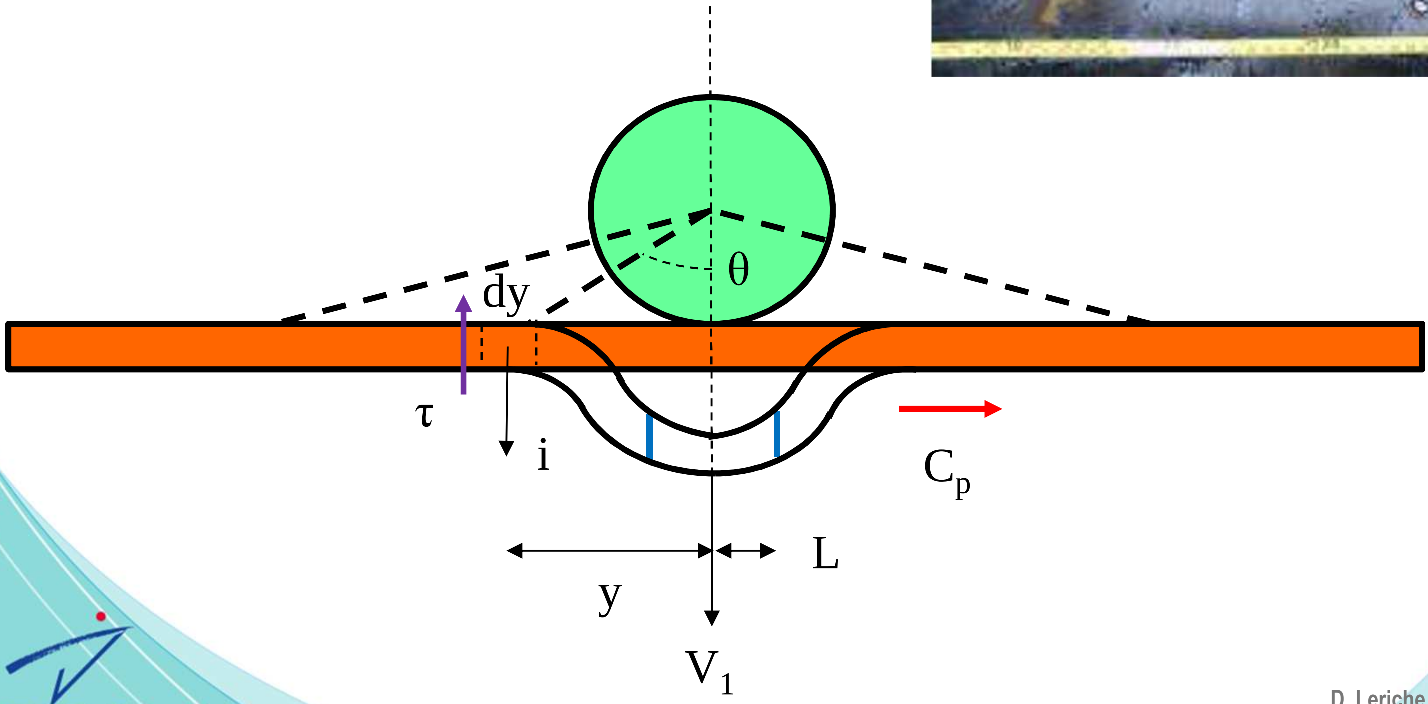


We can show :

$$X = 0{,}785.r_0 \approx L$$

EXPLOSIVE CLOSE TO A METALLIC PLATE : Momentum balance

Transversal shear wave displacement



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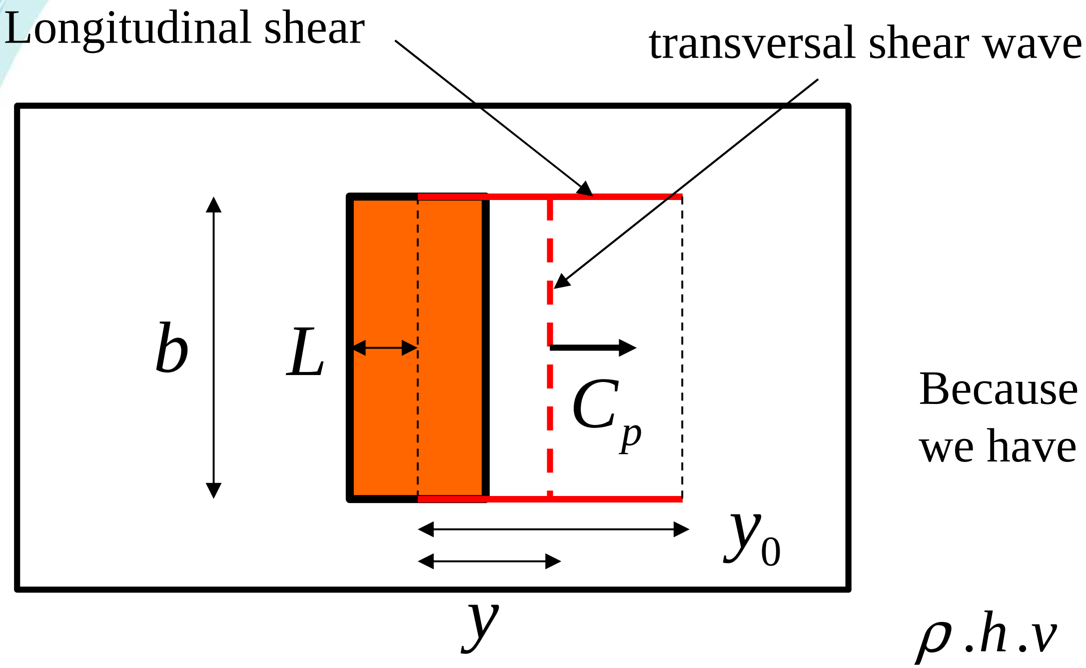
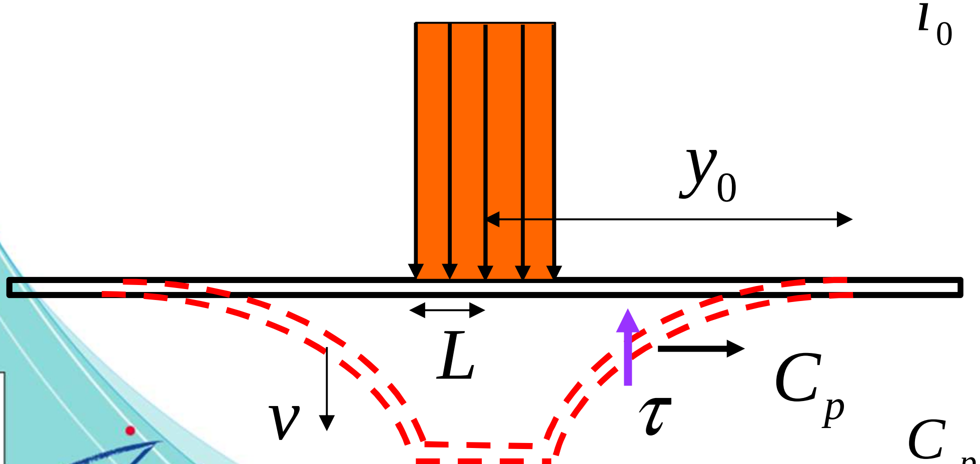
EXPLOSIVE CLOSE TO A METALLIC PLATE : Momentum balance



Because the momentum conservation, we have :

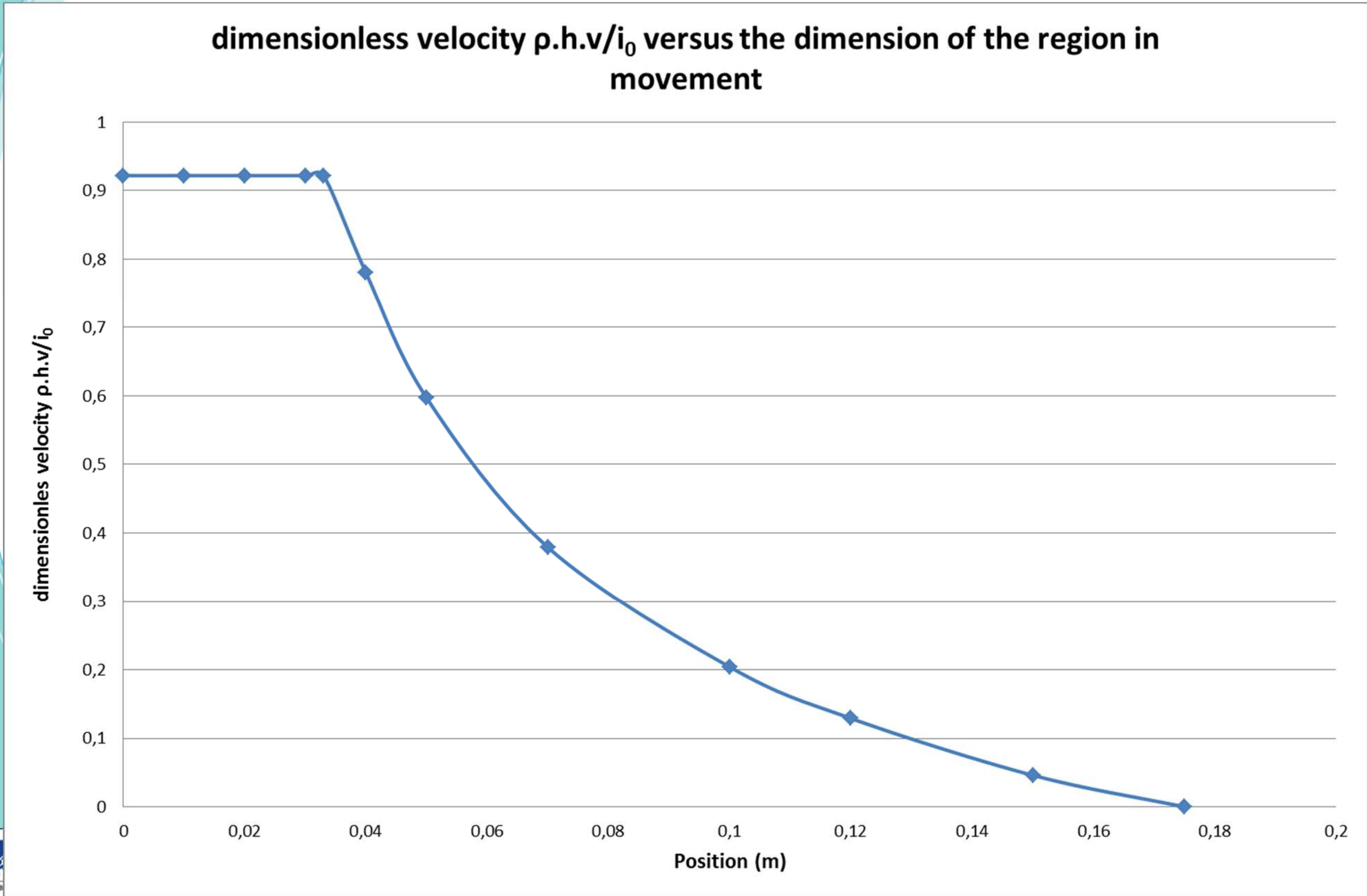
$$\frac{\rho.h.v}{i_0} = \frac{1 + j.\left(1 - \dfrac{y}{L} - \dfrac{y^2}{L.b}\right)}{\dfrac{y}{L}}$$



with : $$j = \frac{\tau.h}{i_0.C_p}$$

$$C_p \approx 500\ m/s - 600\ m/s$$

EXPLOSIVE CLOSE TO A METALLIC PLATE : Momentum balance



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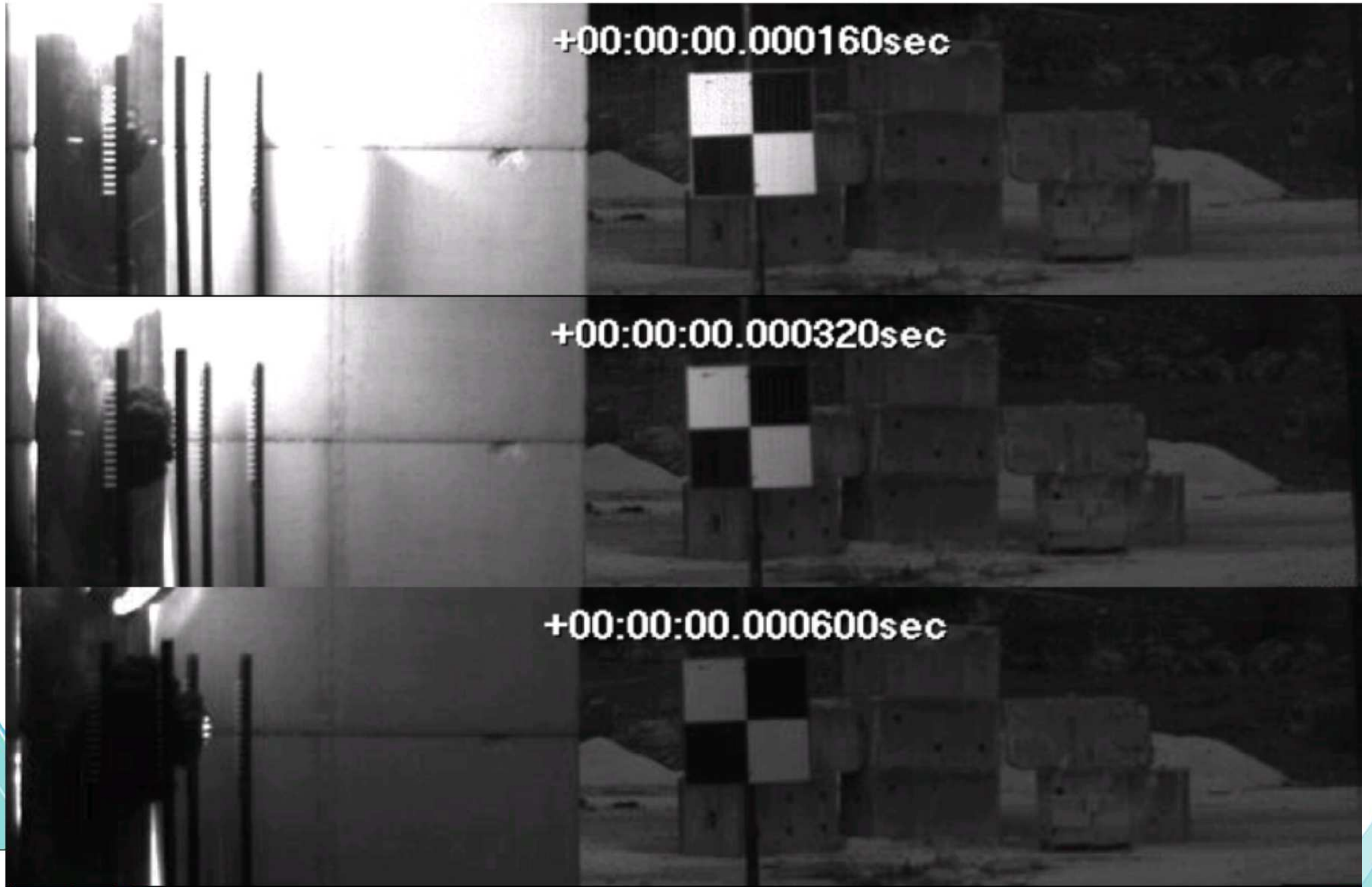
EXPLOSIVE CLOSE TO A METALLIC PLATE : Picture of the phenomenon

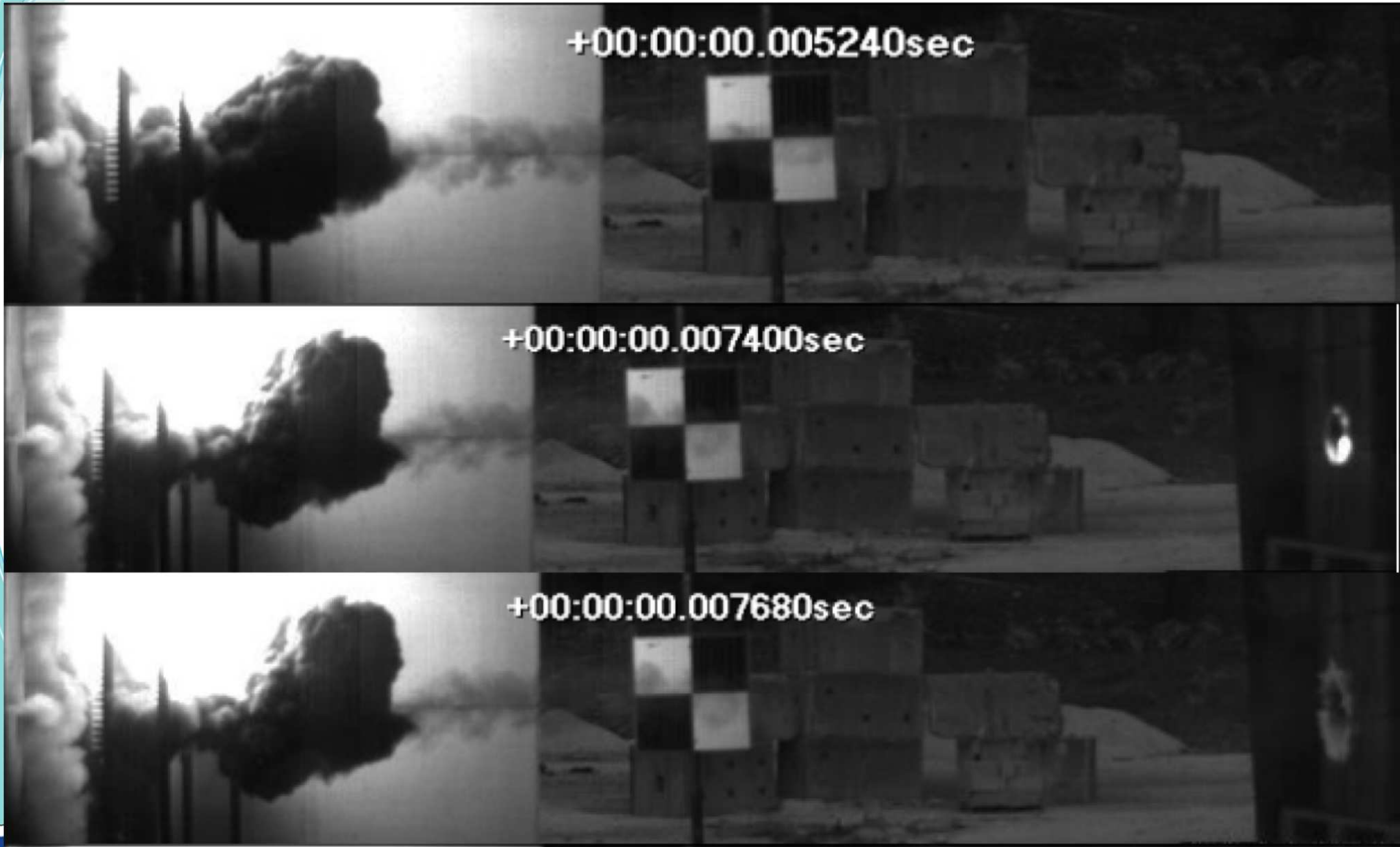


Local deformation of the plate

EXPLOSIVE CLOSE TO A METALLIC PLATE : Picture of the phenomenon

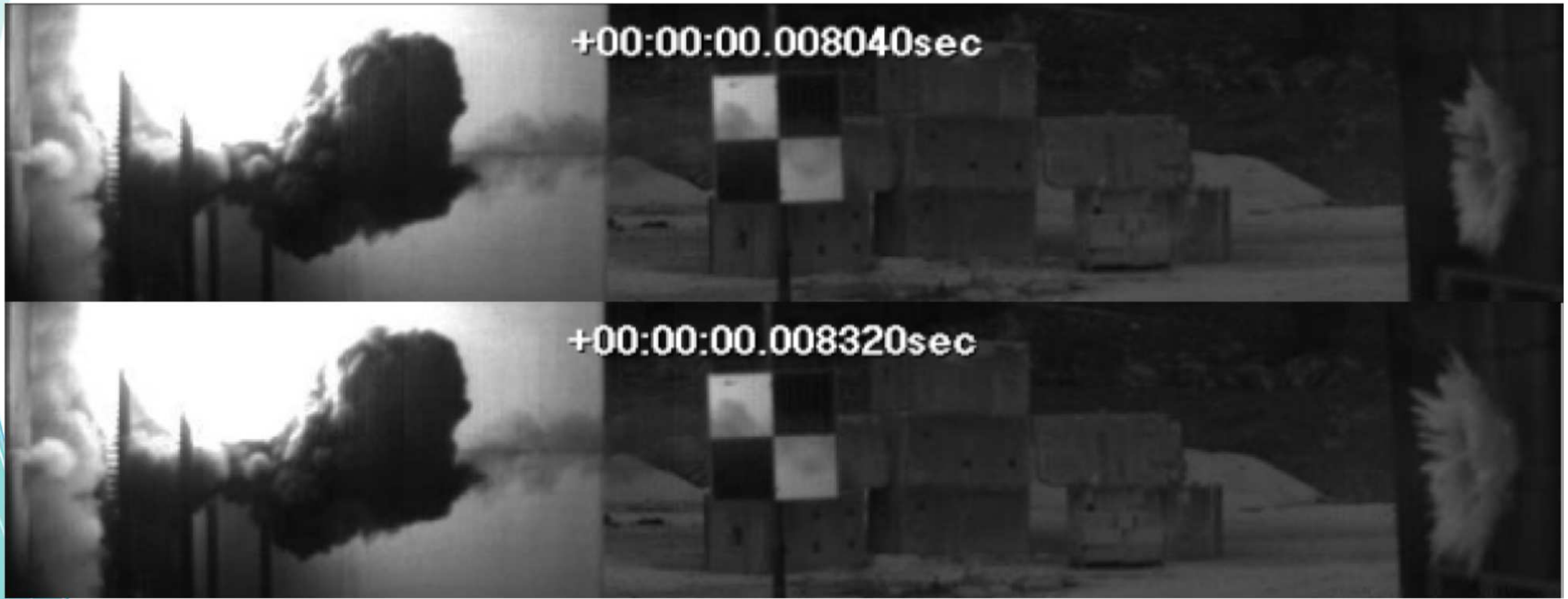
Ejection of the central part of the plate

EXPLOSIVE CLOSE TO A METALLIC PLATE : Picture of the phenomenon



Beginning of the impact of the ejected part on the witness plate

EXPLOSIVE CLOSE TO A METALLIC PLATE : Picture of the phenomenon



End of the impact of the ejected part on the witness plate

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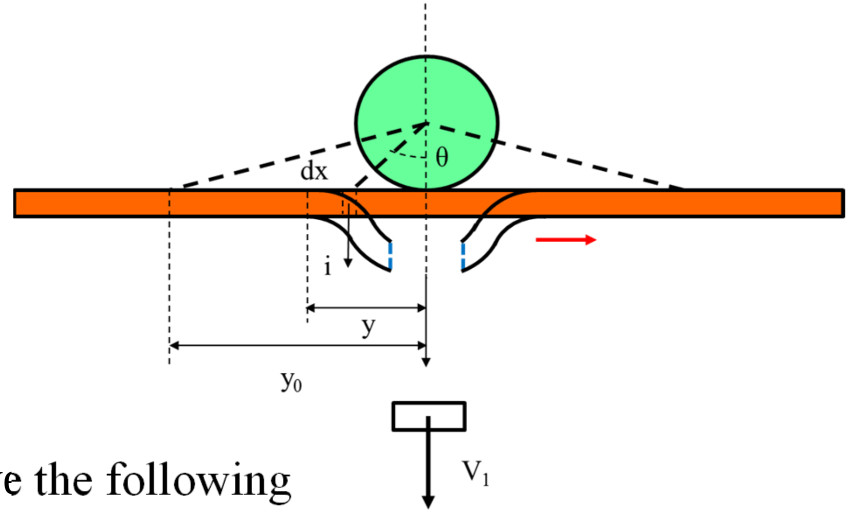
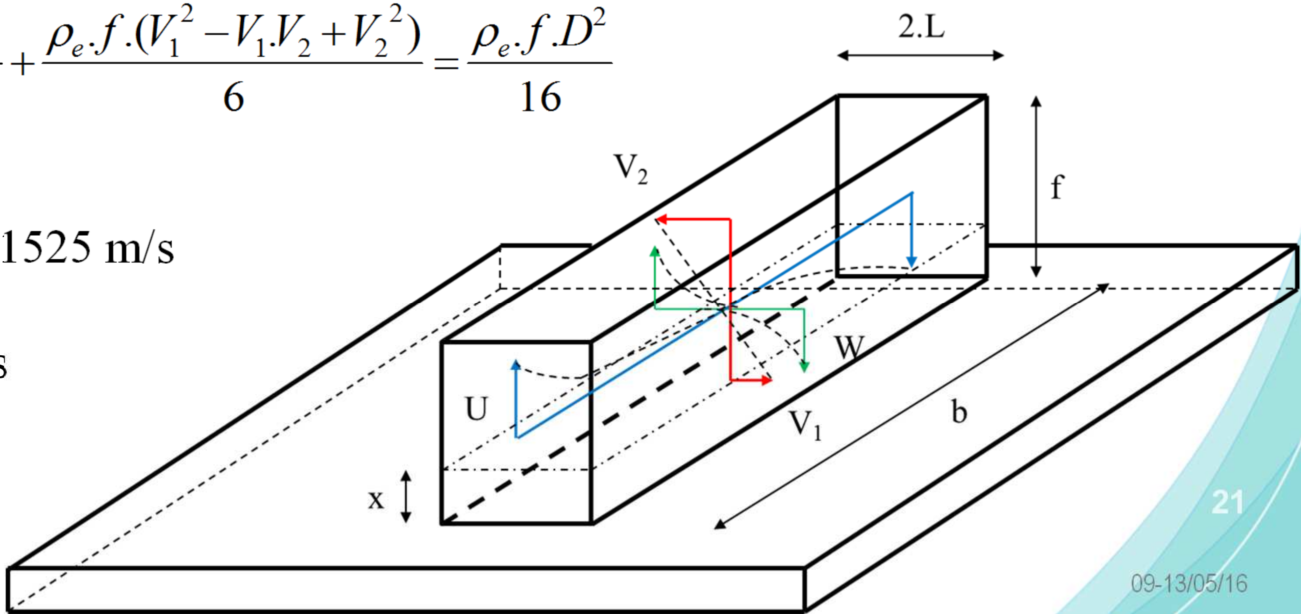
EXPLOSIVE CLOSE TO A METALLIC PLATE : Local ejected part velocity



We use the Gurney's hypothesis with some modifications
*momentum conservation
*energy conservation
*constant specific impulse for the free surface
*parabolic shape of the velocity field for the free surface

We have the following relation:

$$\frac{\rho_p.h.V_1^2}{2}+\frac{\rho_e.f.U^2}{10}+\frac{\rho_e.f.W^2}{10}+\frac{\rho_e.f.(V_1^2-V_1.V_2+V_2^2)}{6}=\frac{\rho_e.f.D^2}{16}$$



Finally we have V_2 = 1525 m/s

and then V_1 = 641 m/s

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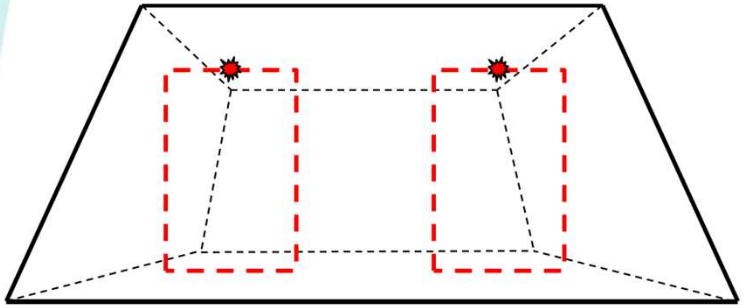
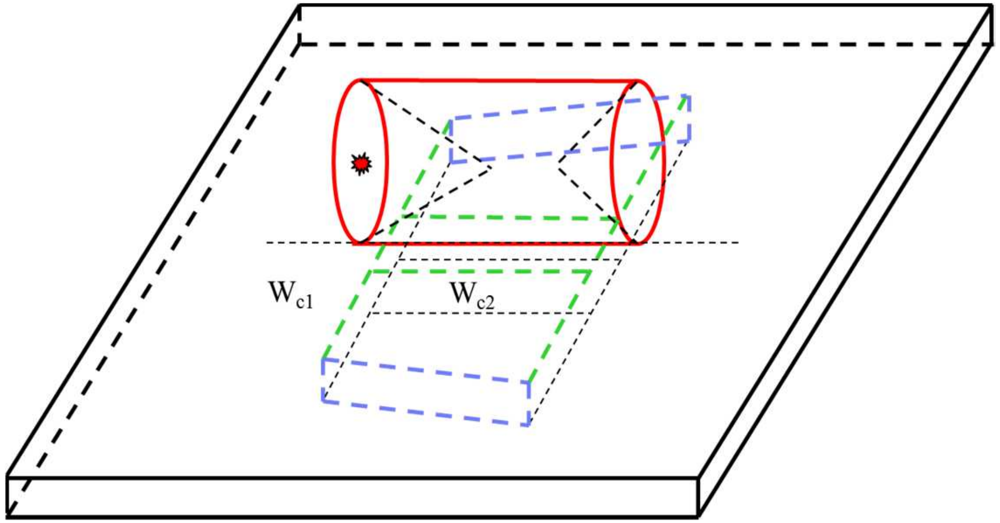
EXPLOSIVE CLOSE TO A METALLIC PLATE : both close charges

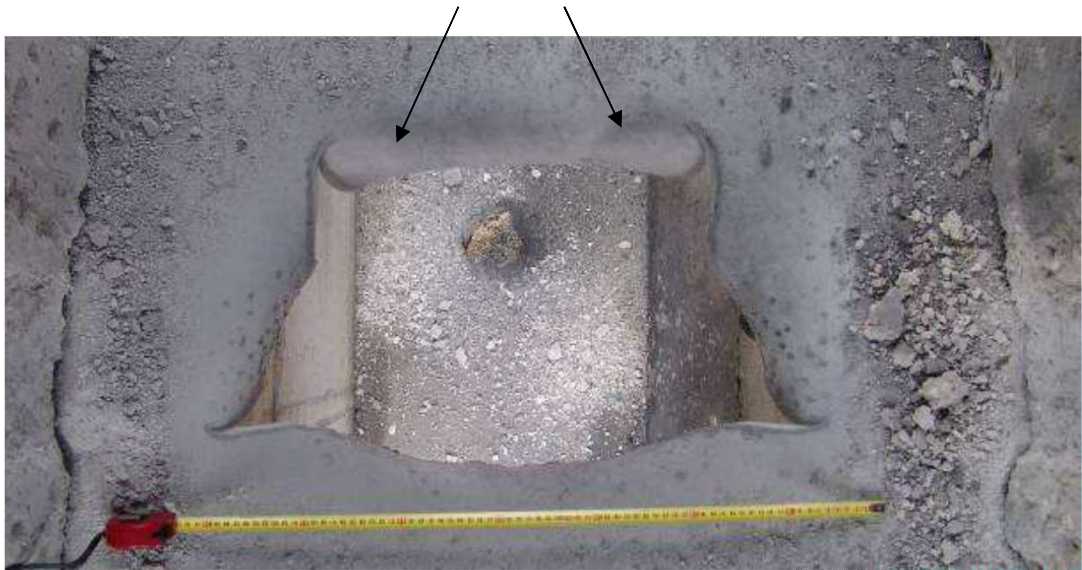
Shear line

Plastic hinge

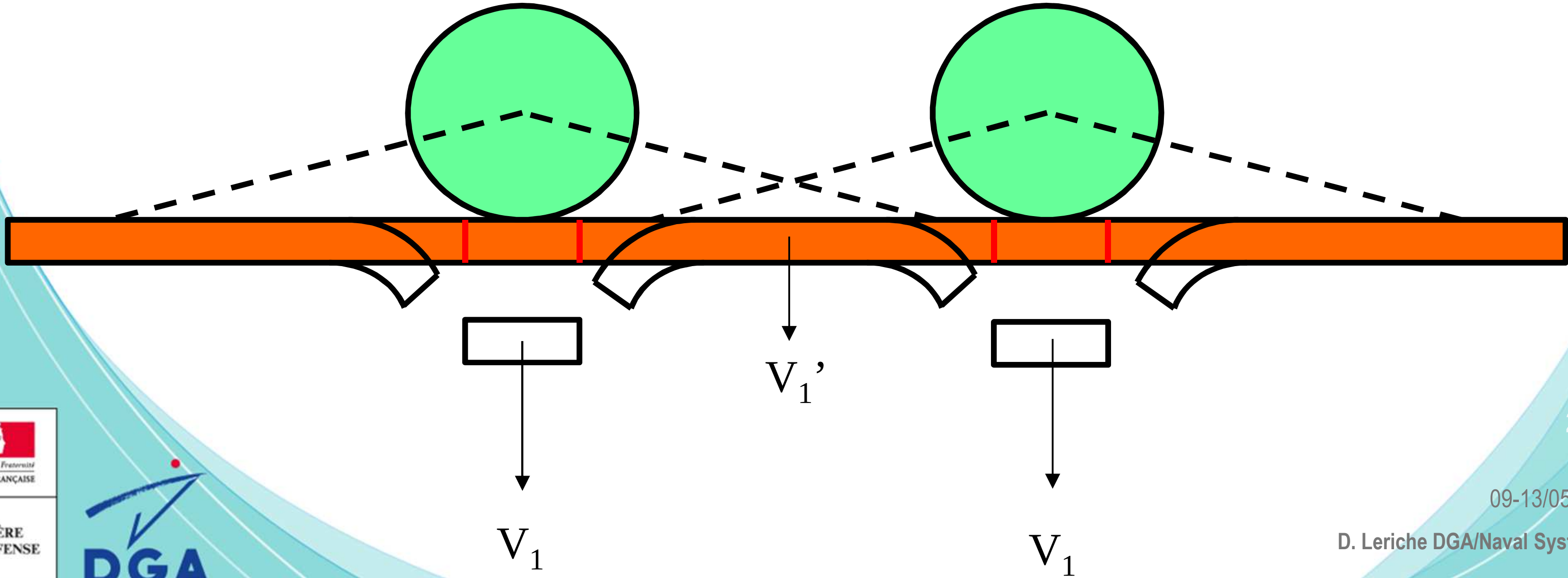




Initiation



EXPLOSIVE CLOSE TO A METALLIC PLATE : both close charges



EXPLOSIVE CLOSE TO A METALLIC PLATE : conclusion

Conclusion

*Energy balance between the explosive and different mechanisms of deformation (shear, bending)

estimation of the specific energy of the explosive loading on the plate.

*Assumption of the transverse displacement as a result of a shear wave moving with a constant velocity parallel to the surface of the plate

estimation of the velocity field of the plate following the loading impulse from the explosive.

*From the Gurney's relation

determination of the local initial velocity of the plate. (calculated value 640 m/s, experimental value 700 m/s)

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